ably in indicating the nature and value of the contribution which each of them made to biological science. He is especially happy in his treatment of the three representatives of ancient research; but the essays on Vesalius and Harvey are also clear, well-arranged, and suggestive. Mr. McRae is not content with second-hand information. He has evidently studied the original sources with care; and the result is that his method of exposition is invariably fresh and interesting. He knows, too, how to connect the results attained in former times with those at which later anatomists and physiologists have arrived. He does not, of course, claim to have exhausted the interest of his subject. But the work he has done, so far as it goes, is sound, and should be of service to many of his readers in helping them to understand the various stages in the development of the scientific conceptions with which he deals.

Through Magic Mirrors. By Arabella B. Buckley. (London: Edward Stanford, 1890.)

THIS volume is intended to form a sequel to the "Fairy-Land of Science," and is written with the clearness and brightness which make that book so attractive. The power that Miss Buckley has of interesting young people in the more popular parts of the various sciences cannot be doubted, and is well shown in the present book. A magician is supposed to teach young lads; and the author is thus enabled to bring in different parts of the sciences, and to preserve a continuity throughout.

There are ten chapters, and the following are some of the headings: "The Moon," "Life-History of Lichens and Mosses," "History of a Lava Stream," "An Hour with the Sun," "An Evening with the Stars," "Little Beings from a Miniature Ocean, &c." In the chapters with these headings the uses of the telescope, spectroscope, camera, microscope, &c., are all mentioned and well explained, and their principles clearly brought out.

The information throughout is up to date, and is taken from the best sources; and the illustrations form a most important addition to the text. The frontispiece is a reproduction of Mr. Isaac Roberts's most exquisite photograph of the great nebula of Orion, taken on February 4, 1889.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Proposed South Kensington and Paddington Subway.

ALTHOUGH there can be no question but that any facilities of access to the group of buildings on the ground of the Commissioners of the Exhibition of 1851 will be greatly to the advantage of the public, the objections to the proposed railway raised in your recent article on "Shaking the Foundations of Science" are worthy of most serious consideration, if they are not altogether fatal to the scheme. The alternative route for the line which you suggest, along Queen's Gate, would meet with equal difficulties, much greater expense, and certain opposition in several quarters. There is, however, another solution of the question free from most of the objections to both the others.

Let the existing subway be continued as originally projected as a walking road to a station at the Albert Hall; and let the tramway or railway line be brought across Kensington Gardens from Paddington to meet it there. This will have the desired effect of giving easy access to the Albert Hall and neighbourhood from the north-west of London, as well as a convenient dry covered approach from the South Kensington Station. The cost of this scheme to the promoters of the railway will be far less than if they have to enlarge the present subway so as to make it available for carriages. The convenience to the public will be nearly as great. In the proposed scheme anyone coming by the District Railway must change carriages at the South Kensington Station; and there are few who, having once alighted, would not as soon take a short walk to the Museums or the Albert Hall through the subway (as was originally designed when this was made) as mount into another carriage. It will be a totally different thing from having (as now) to emerge to the upper surface, and either take a cab or trudge along a wet, dirty, and cold road. It would, in fact, be scarcely a longer walk than is often necessitated along the platforms of some of our existing railway stations.

The walking subway, instead of opposition, may well receive the cordial support of all interested in the "foundations of science," as it will lessen the number of wheels which rattle along the streets above. The marvellous improvement that it made in the state of the streets during its brief period of usefulness, the summer of the Indian and Colonial Exhibition, was apparent to all dwellers in the neighbourhood.

W. H. FLOWER.

Natural History Museum, January 12.

WOULD it not be desirable to prepare a petition to the House of Commons, to be signed exclusively by scientific men, against the proposed South Kensington and Paddington Subway Railway? A copy might lie for signature at the rooms of each of the learned Societies. ALFRED W. BENNETT.

Chemical Action and the Conservation of Energy.

IN NATURE of December 18, 1890 (p. 165), there appears a paper by Mr. Pickering under the above heading, in which some of the errors of thermo-chemists are exposed. As, on account of the well-known experimental skill of Mr. Pickering in thermo-chemistry, there may be some risk that all the positive statements in this paper may be accepted by students as facts, it is, I think, worth pointing out that some of these statements, although given positively as if they were obvious physical laws, are, to say the least, matters of controversy, whilst others are absolutely erroneous. It would seem as though prolonged calorimetrical studies lead the experimenter to regard heat changes as the only factors to be considered in cases of chemical equilibrium, since the same erroneous view of the subject has been taken by Berthelot in his "Law of Maximum Work," by J. Thomsen in a similar "Law," and now by Mr. Pickering in this paper. He concludes:—

"As a consequence of this, it follows that, in any complex system of atoms, where two or more different arrangements are independently possible, and where the various products remain within the sphere of action, and are capable of further interaction, then those products, the formation of which is attended with the greater evolution of heat, will be formed to the exclusion of the others."

It is somewhat curious that by way of clearing the ground for his own views Mr. Pickering demolishes one of the chief arguments of the older school—namely, that an endothermic reaction may occur if it forms part of a cycle of which the final result is an evolution of heat. His illustration of the impossibility of this, by comparison with a stone rolling a short way up a hill by itself in order to have a long roll down on the opposite side, is exceedingly apt. But immediately following this is a statement which must be regarded as incorrect: "No amount of heating can make an endothermic reaction possible so long as it remains endothermic."

I have characterized two statements as erroneous; perhaps I may be allowed to mention the evidence usually accepted as proving this, premising that, since it partially depends on the second law of thermodynamics, and this in its turn depends upon experiment (see J. J. Thomson, "Application of Dynamics to Physics and Chemistry," pp. 4 and 5), no argument against it is valid which deals only with single molecules. The researches of J. W. Gibbs (Trans. Conn. Acad., iii. 108, 343), of Lord Rayleigh (Proc. Roy. Inst., vii. p. 386), of Massieu (*Journ. de Phys.*, vi. p. 216, and of Helmholtz (*Sitz. Akad. Berl.*, February 2, 1882, July 27, 1883, and *Monats. der Berl. Akad.*, May 31, 1883, p. 647; also, Physical Society, Translated Memoirs, vol. i., Part 1), prove conclusively the general principle that the evolution of heat alone is not conclusive as to the possibility of a chemical change taking place in a given direction. The magnitude which does condition this change having been arrived at by different methods, in some cases independently, has received different names; thus it is the "free energy" of Helmholtz, the

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"characteristic function" of Massieu, the "force function for constant temperature" of Gibbs, and the "thermodynamic potential" of Duhem. All these names represent the same function, F (or $-F$), the integral energy (U) less the product of the absolute temperature (T) into the entropy (S); or in symbols the free energy $F = U - TS$. In the above-mentioned researches it is shown that a system will be in stable equilibrium if the free energy is a minimum. Hence, to restate Mr. Pickering's conclusion, it follows that, in any complex system of atoms or molecules, where two or more arrangements are independently possible, then the final arrangement will be such that its formation is attended with the greatest loss of "free energy." Although this work has now been published nearly fifteen years, so far as I am aware no serious attempt has been made to prove it to be inaccurate.

Let the energy, entropy, and temperature before the reaction be U, S, and T; after the equilibrium is established, U', S', and T', then $(F - F') = (U - U') - (TS - T'S')$. But $(F - F')$ must be positive, *i.e.* $(F - F') > 0$. If the temperature be so low that the second term is small compared to the first, then there will be loss of energy—an evolution of heat. But this is not the only possible case; the reaction may take place with an absorption of heat if $T'S' > TS$, and also $(TS - T'S') > (F - F')$. Here $(U - U')$ is essentially negative; in other words, the reaction will take place of itself and with absorption of heat. This will account for many apparent anomalies in high temperature reactions.

Further, as regards the statement that "no amount of heating can make an endothermic reaction possible so long as it remains endothermic," we see from the equation $F = U - TS$ that the importance of the second term increases with the temperature, and thus F may decrease by the increase in TS as well as by the more generally recognized decrease in U. U may, in fact, increase in the course of the reaction, provided that the corresponding increase in TS is larger.

Exception might also be taken to the definition given of chemical affinity as "the potential energy possessed by atoms." It is rather difficult to imagine potential energy becoming "satisfied" when the atoms combine together. As, however, there are now several works giving a complete account of the other views on this subject, it is unnecessary to discuss this point.

In conclusion, it may be as well to point out that the above remarks contain nothing new, having been known for years; but as they have not yet found their way into the text-books of thermal chemistry, and are apparently ignored by our leading thermo-chemists, it seems worth while to bring them to the notice of students. GEORGE N. HUNTLY.

Richmond, Surrey, December 22, 1890.

Forestry in North America.

THE timber-cutters, graziers, and settlers, who are rapidly destroying the forests of North America have recently obtained a valuable ally in Major J. W. Powell, Director of the United States Geological Survey; who, in his enthusiasm for the construction of dams, appears to care little from whence his countrymen are to get their future supplies of timber, whilst his proposed means for securing to them a perpetual water-supply for irrigating the farm lands below the Rocky Mountains, when confronted with the experience acquired in Europe, are likely to prove worse than useless. Most students of physical geography consider hill forests as efficient aids in storing water, but not so Major Powell; for in the April number of the *Century Magazine* in a paper on the "Non-irrigable Lands of the West," and in another paper published in the August number of the *North American Review*, entitled "The Lesson of Conemaugh," he advocates the denudation of the higher slopes of the Rocky Mountains, in order to allow snow-drifts to accumulate in the folds of the hills, and afford a perennial supply of water for irrigating the drier lands below the forest belt. Major Powell contends that, as long as the higher hill slopes remain forest-clad, the snow falling on them will always be uniformly distributed, and cannot be drifted together by the wind. It therefore melts away gradually, without affording a steady supply of water to the hill streams. He also asserts that in California the hill streams have increased wherever the hills have been denuded; and expresses his opinion that, although forests may be useful in districts with a heavy rainfall, as they evaporate excessive moisture rapidly from the soil, yet in drier regions this rapid evaporation is prejudicial, and therefore forests should be cleared in order to preserve the requisite amount of moisture in the soil. This appears to be a complete inversion of what actually occurs, as I hope to show further on.

Major Powell gives a most striking picture of the ease with which forest denudation may be effected in the dry coniferous forests of the Rocky Mountains. When camping out twenty years ago in this magnificent forest tract, where the growth was then so dense that not a blade of grass was to be found under the trees, but the soil was completely covered with dead needles; the Major allowed his camp fire to ignite a splendid pine tree, and watched the "welcome flame" rising till the whole tree was in a blaze. The fire soon spread to the surrounding forests, and before nightfall the country for miles around was in flames, more timber being destroyed in a few days than "has been used by the people of Colorado for the last ten years."

Major Powell, however, as we have stated, would preserve forests in the damper regions, and admitting the danger of forest fires to their existence, he proposes as a remedy a great extension of sheep-farming; so that the undergrowth of the forests may be nibbled off, and thus a great source of danger from fire may be removed. What the sheep are to find to nibble in forests where the soil is covered with dead needles, it is not easy to say; and if all undergrowth be bitten off by the sheep, the future re-growth of the forest could evidently not be assured by natural seedlings, but the older portions must be gradually fenced and planted up: if this be done on a large scale it is to be feared that even the vast resources of the States would prove inadequate. An answer has, however, already appeared in an American periodical, *Alta California*, to the Major's suggestions regretting the progress of forest arson, and anticipating that thousands of acres of the noblest timber in the world will be destroyed before the first rains next autumn. The writer states that these forest fires are chiefly due to shepherds, who burn the pine needles, and consequently the entire forest, in order to get young grass to spring up for their flocks.

So much for the real results of extending sheep-runs to preserve the forest from fire, which reminds one of a suggestion in Prof. Wallace's "Indian Agriculture"; except that this author goes further than Major Powell, and wishes to induce the Government of India to put an end to the efforts of the Indian Forest Department to protect their forests from fire, considering that Indian forest trees have grown up under a *régime* of annual fires till they have become quite inured to them, and would suffer if the fires were stopped. The Professor also urges that the Indian flocks and herds would miss the fresh young grass always springing up in burned forest, but if admitted to graze in the annually burned area, would keep down the undergrowth, the occasional burning of which in a forest protected from fire, according to him, does more damage than annual fires in well-grazed forests. It is to be feared that both the Edinburgh Professor of Agriculture and the Director of the United States Geological Survey have more sympathy for the shepherds than for the forests.

Besides the paper controverting the Major's advocacy of sheep as friends to the forest, I was glad to see two very sensible articles, in *Garden and Forest* of June 18 and September 4, entirely opposed to his theories, whilst Mr. Abbot Kenney has written a paper in the August number of the *Century* showing that the statement about the increase in volume of the hill streams in California being due to forest denudation, is at variance with the facts of the case.

There can be no doubt that directors of geological surveys should study the action of the forest as a great natural factor influencing soil and climate. In Germany, the elements of forestry are taught in primary schools as a necessary part of the general education of the country people; but the German peasants have owned forests, and participated in their benefits, for centuries, and a forest fire in France or Germany is considered a great calamity by the whole country-side: the Anglo-Saxon race on the contrary has been chiefly engaged during the last 300 years in clearing away the virgin forests of the new worlds in the western and southern hemispheres; and, as we see, the benefits of forests are still questioned by certain influential people both here and in America.

Darwin and A. R. Wallace admit over and over again the inestimable value of the forest as Nature's great conservative force; and in America, Major Powell's heresies were long ago disposed of in Marsh's "Man and Nature." In Wallace's

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